

Technical Report 005

Information Paper  
on  
HDTV Formats



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## Information Paper on HDTV Formats

**Keywords:** HDTV Format, 720p/50, 1080i/25, 1080p/50

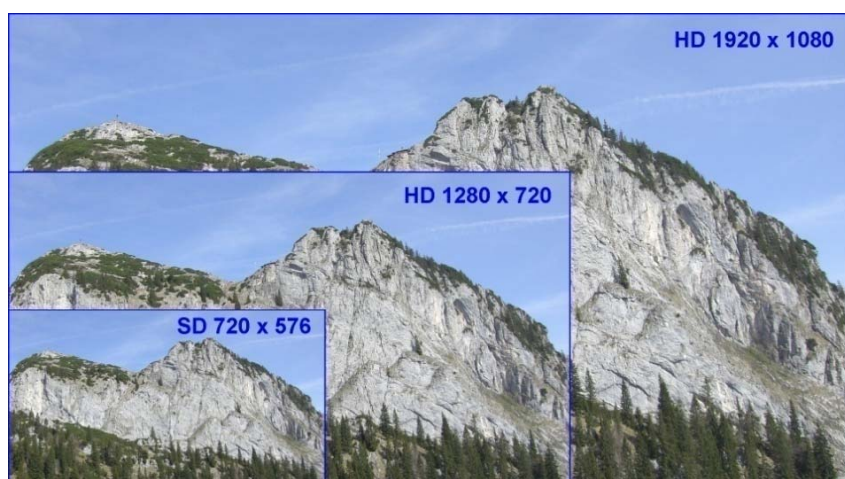
High Definition Television (HDTV) for consumers and professionals has given rise to a partly emotional discussion about HDTV image formats. This paper discusses the issues of HDTV image formats from a technical and objective point of view.

In Tech 3299-2009, the EBU defined four HDTV base-band formats annotated as system 1 to 4. Two formats are predominantly used as emission/distribution formats. System 1 - 720p/50 and system 2 - 1080i/25<sup>1</sup> are discussed in this document.

At first sight a consumer might think that a higher number ('1080 is bigger than 720') would also mean a better-perceived image quality. However both formats have been shown to deliver good HD image quality. Due to certain technical particularities, the 720p/50 image format is recommended by the EBU Technical Committee as the optimum solution for current HDTV-emissions (R112-2004). It is important to note that almost all displays and receivers in Europe that support the HD-Ready, HDTV, HD-ready 1080p or HDTV 1080p labels are compatible with both of these HDTV formats (see Appendix 3).

### 720p/50 and 1080i/25 – the differences

As a first impression, the biggest difference between the two image formats seems to be in the spatial resolution, that is, the number of pixels. Many publications use diagrams such as **Figure 1** to visualize the difference in pixels and to promote one format over the other. In particular, such diagrams are used to promote the 1080i/25 HDTV format over the 720p/50 format, but this is not the whole story.



**Figure 1:** Visualisation of the numerical comparison between the Standard Definition TV format, and the two HDTV formats.

An image with less pixels displays less detail. This results in the assumption, that the 1080i/25 format with 1920 x 1080 pixels would provide a better image quality than the 720p/50 format with 1280 x 720 pixels.

Since this assumption is only valid for still images it is not entirely correct. See also the Table 1, comparisons of net-bitrates.

<sup>1</sup> 720p/50: 50 full frames, each with 720 lines and 1280 pixels per line. 1080i/25: 25 full frames per second or 50 half frames (known as fields) with each field having 540 lines and 1920 pixels per line. Note that some 1080i/25 broadcasts use horizontal sub-sampling to 1440 pixels per line.

The only case for which this type of diagram is valid is with still image capture and representation. This ignores the fact that television is inherently about moving images and that it aims to bring the reality of sports and other events home to the consumer. With the 1080i/25 format, 50 fields (half frames containing only 540 lines) are transmitted per second, whereas the 720p/50 format contains 50 full-frames with 720 lines per second (therefore it is designated 720p/50). In consequence 720p/50 offers double the number of full frames per second than the 1080i/25 format. The 720p/50 format provides a detailed motion rendition and increases the perceived sharpness of moving scenes.

The transmission of half frames (fields) in the 1080i (i=interlaced) HDTV format is using line-interlacing, a technique that was developed to save bandwidth in the early 1930s for Standard Definition Television (see Appendix 2).

Today, flat panel displays and projectors inherently display full frames containing all the lines that make up the picture (so called progressive display). This progressive display of television images requires that interlaced formats such as 1080i/25 HDTV or 576i/25 SDTV are 'de-interlaced' within the display device (or set-top box) before they are presented to the display electronics.

De-interlacing describes a process that is applied to the digital image to calculate (and, in the worst case, to estimate) full frames from successive fields. Depending on the quality of the de-interlacing image processing applied and in particular, with moving objects or with camera pans, a loss of sharpness and even a reduction in the final vertical resolution of the 1080i/25 format to lower than that of the 720p/50 format can be the consequence. These effects are termed motion artefacts.

The 720p/50 (p= progressive, full frame) format exploits the temporal resolution of 50 frames per second (with 720 lines). De-Interlacing is not required and motion artefacts caused by interlaced scans do not exist. It must be noted however that 1920 x 1080 pixel consumer displays require the 1280 x 720 pixel broadcast HD signal is scaled to the 1920 x 1080 pixel resolution of the display (similar to the scaling of 1440 x 1080i/25 broadcasts to the display resolution).

It needs to be recognised that most international HDTV-events are made in either 1080i/25 or 1080i/29.98 (for 60 Hz countries). Presenting 1080i/29.98 in 50 Hz countries will require frame rate conversion. For content produced in 1080i/25, 720p/50 broadcasters will need to de-interlace the signal before emission, but for 1080i/29.98 content, frame rate conversion AND de-interlacing is required.

De-interlacing is not a transparent process. The final image quality resulting from the mathematical process of de-interlacing depends on the algorithms employed and the processing power of the de-interlacer used, but some motion artefacts are an inevitability. Consequently the 720p/50 broadcaster must decide which de-interlacer to use (the EBU recommends motion-compensated de-interlacers). 1080i/25 broadcasters have to accept that their de-interlacing is carried out in the consumer display. Although older consumer displays tended not to do this well, recent, higher-end displays can have reasonably good de-interlacers.

Finally, careful attention should be paid to the default settings of HDTV receivers as they do not always automatically present the incoming HDTV format to the display (e.g. 720p/50 receiver input converted to 1080i/25 display interface or vice-versa). It is a good idea to follow the guidelines given in EBU Tech 3333, the EBU HDTV receiver requirements document (see §4.5.3 output format).

A more objective comparison between the different HDTV formats is provided by comparing the actual information pixel bit-rates. This is shown in the following table.

Table 1: Net-pixel bit-rate of the different HDTV broadcast standards.

HDTV broadcast format (uncompressed)	Net Pixel Bit-Rate (uncompressed)	Comment
1280 x 720p/50	0.53 Gbit/s	
1440 x 1080i/25	0.44 Gbit/s	Many 1080i/25 broadcasts use line-sub-sampling to reduce bit-rate
1920 x 1080i/25	0.59 Gbit/s	
1920 x 1080p/50	1.2 Gbit/s	Today, no broadcasts are available in 1080p/50

Note that the above bitrates have been calculated for broadcast formats (4:2:0, 8 bit) and not for their corresponding production formats (4:2:2, 10 bit).

## What counts is the perceived image quality!

Internationally recognised and standardised tests have been performed by bodies such as the 'Institut für Rundfunktechnik' (IRT, in Munich), the European Broadcasting Union (EBU, in Geneva) and by various other broadcasters. Non-expert and expert viewers alike have been shown 720p/50 and 1080i/25 HDTV content and have provided a subjective rating of their viewing experience.

Because of the human visual system and the natural resolution of the human eye it is usually necessary to sit closer to the display in order to experience HDTV quality. Therefore the subjective tests referred to were conducted with 50 inch diagonal HDTV displays (1920 x 1080 pixel resolutions) and at a viewing distance equivalent to three times the picture height.

The tests revealed that at the same distribution bitrate the 720p/50 format images were more appreciated by the viewers than the 1080i/25 format images. EBU Recommendation R124 relates to these tests. In addition the tests revealed that progressive source images can be more efficiently digitally compressed (encoded) than interlaced source images. This can be exploited in two ways.

- Provide a higher image quality with a 720p/50 channel by using the same bitrate originally assigned for the distribution of a 1080i/25 channel, or,
- Provide an equivalent subjective image quality using the 720p/50 format at a bitrate less than that originally assigned for the distribution of a 1080i/25 format.

Comprehensive tests could show the potential of the 720p/50 format.

*Remark: It is useful to be aware that the final HD quality shown to the consumer depends on many factors in a complex production and emission chain. Uniquely the decision of broadcasters to use either 720p/50 or 1080i/25 will therefore not be the only guaranteeing factor for high quality HD content at the consumer premises. In addition, further developments of emission encoder compression algorithms will likely allow the reduction of emission bit-rates for both formats whilst maintaining the HD quality.*

## How to handle movie and documentary HD formats?

Two further HDTV variants exist. The 1080p/24 format and System 3 - the 1080p/25 HDTV format, have become the worldwide de-facto HDTV standards for movies, fiction and documentary productions. Because of their lower frame-rate these formats are not used for sports coverage or for any production with fast motion. Most Blu-Ray Disks (the HDTV-successor of the DVD) use the 1080p/24 'movie type'<sup>2</sup> format.

For distribution/emission of these formats, broadcasters use the technique of progressive segmented frames (psf). For 1080i/25 distribution, one 1080p/25 frame is split into field 1 and field 2 of the interlaced frame. For 720p/50 distribution of the above formats frame doubling (with motion adaptive techniques) is applied.

## What other HDTV formats exist – and what does the future bring?

The 1080p/50 HDTV format is already in discussion for the future. This would provide a combination of the best parts of the 1080i/25 and 720p/50 HDTV formats. It would have the fast temporal motion resolution of the 50 progressive frames (from the 720p/50 format) and the increased spatial resolution of 1920 pixels x 1080 lines (from the 1080i/25 format) without the disadvantages of interlaced scan.

Today there is only a limited amount of production equipment able to generate 1080p/50 content but broadcast manufactures are targeting this format for fast product development.

To receive 1080p/50 signals the viewer would need to replace an existing 1080i/25 - 720p/50 HDTV set-top box, although existing HD-Ready 1080p displays are capable of showing 1080p/50 material via their HDMI interfaces. Any thoughts of distributing 1080p/50 to the home are currently speculative, but there might also be consideration for using the 1080p/50 format to distribute 3D-TV content.

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<sup>2</sup> In order to enjoy 1080p/24 or 1080p/25 formats, television receivers with the 'HD-Ready 1080p' logo of the DigitalEurope association are required. (see Appendix 3).



## Appendix 1: Overview of Television Standards

576i/25	Standard Definition Television (SDTV): This is still the most common signal distributed to the home. It has 576 active lines in interlaced scanning and it operates with 25 frames per second, comprised of 50 fields (half-frames) per second.
1080i/25	High Definition Television (HDTV) with 1080 lines in interlaced scanning with 25 frames per second, comprised of 50 fields (half-frames) per second.
720p/50	High Definition Television (HDTV) with 720 lines in progressive scanning of 50 frames per second.
1080p/24	High Definition Television (HDTV) with 1080 lines in progressive scanning of 24 frames per second. This is the same number of frames per second used in the cinema and it is a format commonly used in Blu-Ray disks.

Nomenclature used in the EBU to denote image formats:

Active lines (576, 720 or 1080) followed by the scanning format (*i* for interlaced, *p* for progressive and *psf* for progressive segmented frames) followed by the number of full frames per second (/24, /25, /50 etc.)

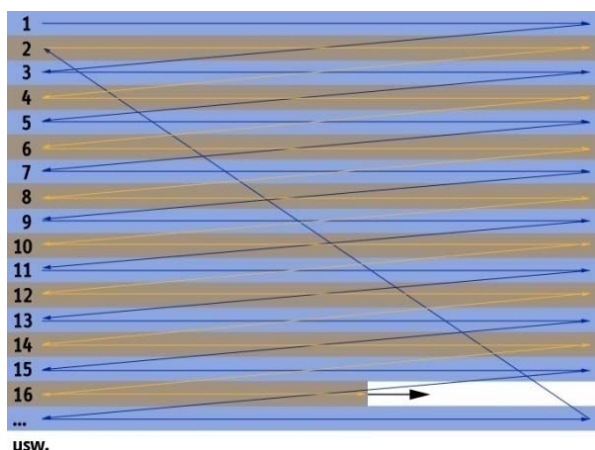
Examples: 1080i/25, 1080p/50, 1080psf/25.

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## Appendix 2: Formats with interlaced fields: historical and sub-optimal

Interlaced scanning exploits the integrating capability of the human visual system for changes in luminance. If the changes in luminance are not fast enough (i.e. repetition of fields or frames) then the human observer detects flicker. Experiment shows that repetitive frames are started to be perceived without flicker from 16 to 18 images per second (depending on the size and brightness of the images), but a flicker-free perception of movement requires 50 frames of 50 fields (half a frame) per second<sup>3</sup>. Cinema movies are usually shot in 24 frames per second. In order to avoid flicker effects in the cinema, each image is presented (projected) twice, resulting in an effective repetition rate of 48 frames per second.



With interlaced scanning each frame is divided into two fields.

One field consists of lines with odd numbers; the next field consists of lines with even line numbers.

This technology was developed in the 1930s to allow a flicker free presentation on Cathode Ray Tube (CRT) television receivers (the only ones then available) and to overcome the limited bandwidth of the then current electronic technologies that were used.

Transmitting 50 frames per second was technologically not possible during the development phase of analogue SDTV in the 1920s-30s. The compromise of interlaced scan was found to provide fast repetition of fields (50 fields per second) necessary to eliminate flicker and at the same time it required only half the signal bandwidth compared to full progressive scanning.

With interlaced scan the images are sampled or scanned line by line; however at each sampling point only half the lines of a full frame image are scanned. The first half-frame (field 1) consists of the odd lines and at the next sampling point the second half-frame (field 2) with the even lines is scanned and transmitted.

Using this method, moving objects in a scene will not be at the same place on an adjacent pair of lines and so the two fields of a frame will contain different representations of the moving objects. This is especially noticeable on vertical edges that move horizontally.

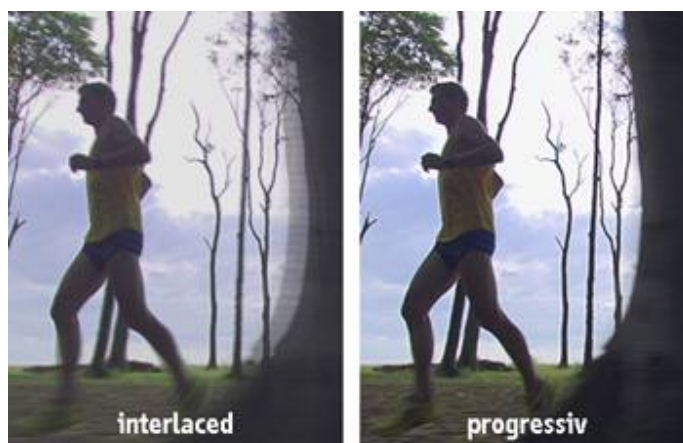
CRT television receivers presented the pictures field-by-field and so were a good match for interlaced scanning. Modern day flat panel displays are composed of a matrix of display elements (plasma, LCD or whatever) that illuminate more-or less simultaneously to present all the details in a frame. Modern flat panel displays are therefore inherently progressive in nature. An interlaced SDTV (576i/25) or HDTV (1080i/25) signal consisting of the two fields has to be converted into progressive frames for presentation on the flat panel display. This so called 'de-interlacing' process can never be perfect and usually requires complex image processing. With moving objects in a scene, typical interlaced image artefacts can become visible in the form of small saw-tooth artefacts on vertical lines and object borders.

<sup>3</sup> Note: this is valid for an average centre-viewing angle. The eye can perceive much higher flicker effects towards the borders of the retina (also depending on brightness and size).

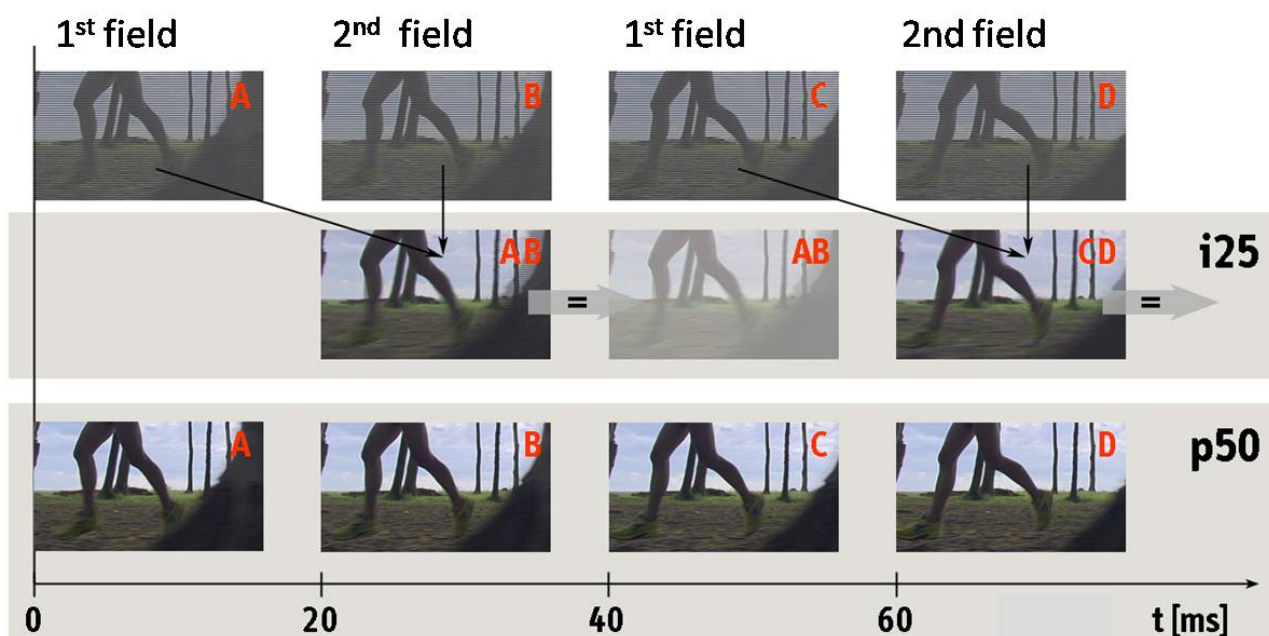
During the presentation of an image consisting of two (interlaced) fields, moving images tend to appear blurred.

This becomes visible in the tree's trunk and leaves of the image on the left, which was scanned in interlace.

The right-hand image shows the same image scanned progressively. Much more detail is evident.



The following figure is a visualization of interlaced scanning (top), a very simplified de-interlacing algorithm (middle), and progressive scanning (bottom).



The letters A-D indicate the different movement-phases. Those movement phases are easily visible around the feet of the runner and in the trunks of the trees.

With the individual half-frames (fields - top images), saw-tooth artefacts are visible, which are caused by missing each second line. For the de-interlacing process which is required by today's flat panel displays, the first even lines field (A or C) and the second odd lines field (B or D) are de-interlaced to a full frame (AB or CD) and, depending on the FPD display technology, are repeated (the transparent AB image) to avoid flicker perception. Because of the fact that the interlaced fields have been created from different movement points, saw-tooth artefacts can become visible.

In contrast, with progressive scanning (e.g. p50) at 50 full frames per second (bottom image row) each movement phase consists of the full information and no saw-tooth artefacts become visible. The motion-portrayal is much improved compared to the interlaced case.

### Appendix 3: ‘HD ready’, ‘HDTV ready’, ‘HDTV ready 1080p’ and what does ‘Full HD’ mean?

Only four logos are officially qualified by the DigitalEurope association (formerly EICTA, see in reference <http://www.digitaleurope.org>). These logos (‘HD ready’, ‘HDTV ready’, HD Ready 1080p and ‘HDTV ready 1080p’ ) are backed by technical specifications.





The different ‘Full HD’ labels on the market are only the marketing inventions of different vendors and do not provide any accredited information about the characteristics of a display.

‘HD ready’ guarantees (amongst other technical details) a display resolution of at least 720 lines in 16:9 widescreen format, and ‘HD ready 1080p’ (amongst other technical details) guarantees a display resolution of 1080 lines in 16:9 widescreen format.

Many ‘HD ready’ displays do not map each incoming signal pixel directly to the screen; rather they scale the incoming signal to the native resolution of the screen or even provide over scan (e.g. up-scaling to 1 - 5% beyond the display resolution, so that in effect some pixels on the borders of an image are not shown). With ‘HD ready 1080p’ displays, over scan can be switched off but up-scaling will always be needed to present 720p/50 signals and SDTV signals in full screen.

Happily it has been found that the subjective image quality is less impacted by scaling than by de-interlacing e.g. a 1080i/25 or SDTV signal for display on a ‘HD ready 1080p’ flat panel display.

It is important for consumers to understand that displays with the ‘HD ready’ or ‘HDTV ready 1080p’ logo and receivers with the ‘HDTV Ready’ logo can operate with 720p/50 and 1080i/25 signals (both are broadcast in various parts of Europe).

	<p>The ‘HD ready’ logo guarantees (amongst other things) native 16:9 aspect ratio and a resolution of a minimum of 720 lines.</p>
	<p>The ‘HD ready 1080p’ logo guarantees (amongst other things) native 16:9 aspect ratio and a resolution of a minimum of 1080 lines.</p>
	<p>Designed for television receivers - including set-top boxes and integrated digital TVs - that can receive and decode HD (720p/50, 1080i/25) satellite, cable or terrestrial broadcast transmissions.</p>
	<p>Designed for ‘HD ready 1080p’ display devices that can also receive and decode HD (720p/50, 1080i/25) Satellite, Cable or Terrestrial broadcast transmissions. Display devices bearing the ‘HD TV 1080p’ logo feature a 1920 x 1080 screen resolution.</p>